4D PhaseCam Capabilities

Multiple-Wavelength Mirror Phasing Modal Analysis

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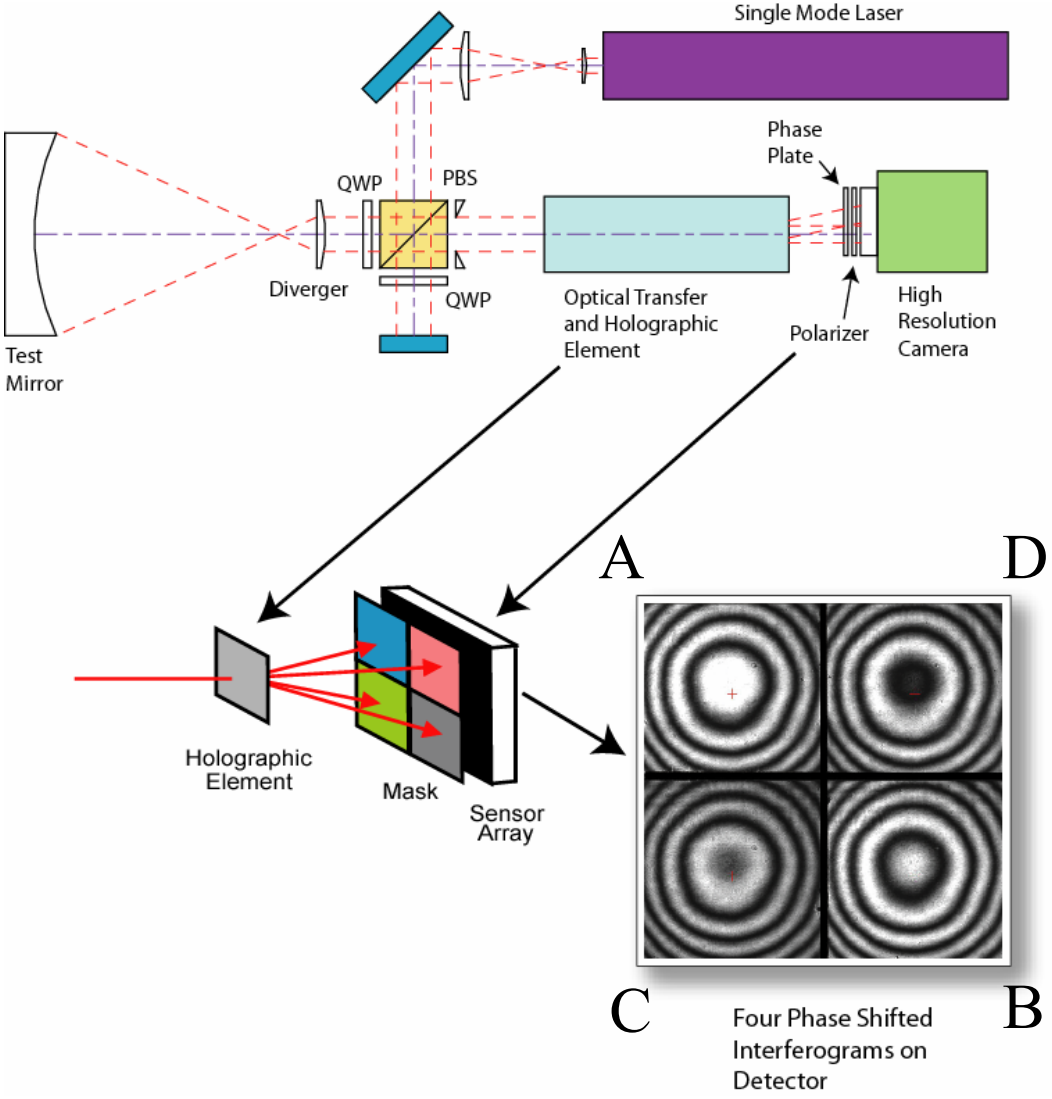
4D PhaseCam Technology



Single Frame PSI

Benefits:

- High resolution interferometric measurement
- Insensitive to vibration & turbulence
- Easy to set up and use

$$\tan\varphi = \left(\frac{B-D}{A-C}\right)$$

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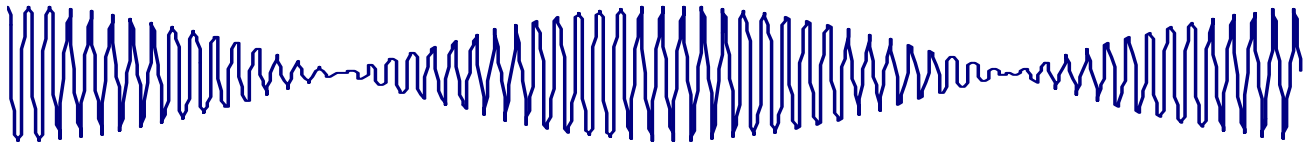
TWO WAVELENGTH MEASUREMENTS

Multiple Wavelength PhaseCam

- 2 Wavelengths can be used to extend range



2 Frequencies beat together to form a long equivalent wavelength

- A measurement is made at each wavelength

$$\Delta opd = 2\Delta z = \frac{\Delta\phi_e}{2\pi}\lambda_e$$

$$\Delta\phi_e = \Delta\phi_1 - \Delta\phi_2 \qquad \lambda_e = \frac{\lambda_1\lambda_2}{|\lambda_1 - \lambda_2|}$$

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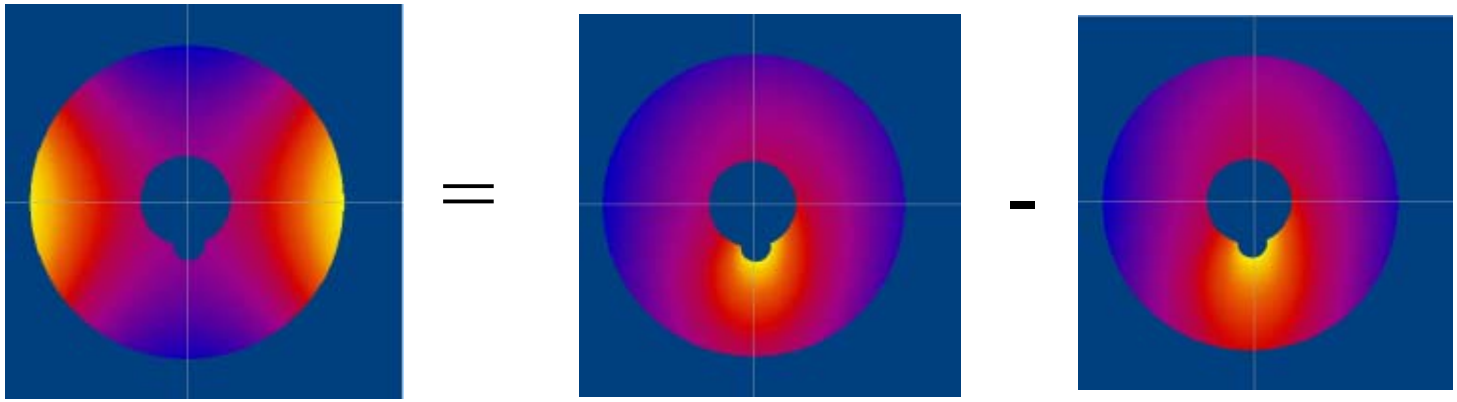
Surface Subtraction

A) Surface domain (specular surfaces only)

$$\Delta Z = Z_t - Z_0$$



measurement *baseline*

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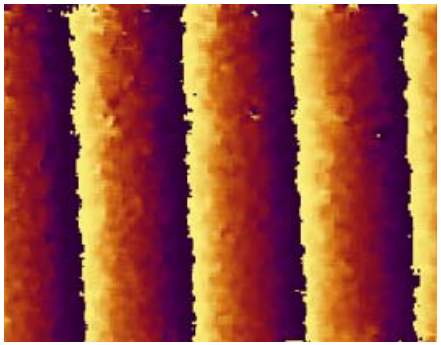
Surface Subtraction

B) Interferogram domain (diffuse and specular surfaces)

Stetson - 8 frame phase-difference

$$\Delta Z = \frac{\lambda}{2}\operatorname{atan}\left(\frac{[D_0 - B_0][A(t) - C(t)] - [A_0 - C_0][D(t) - B(t)]}{[A(t) - C(t)][A_0 - C_0] + [D_0 - B_0][D(t) - B(t)]}\right)$$



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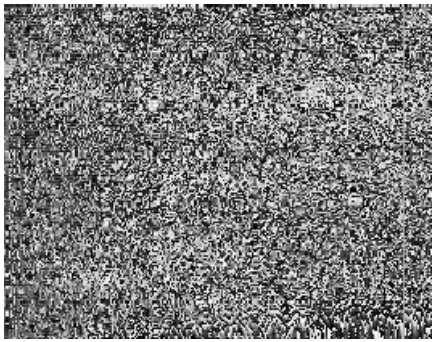
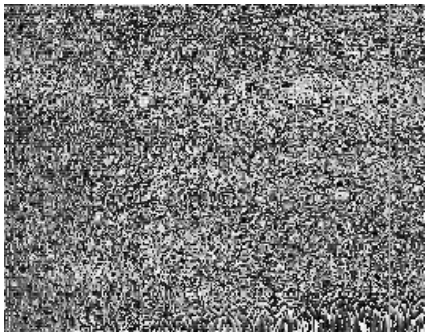
Unwrapping

=



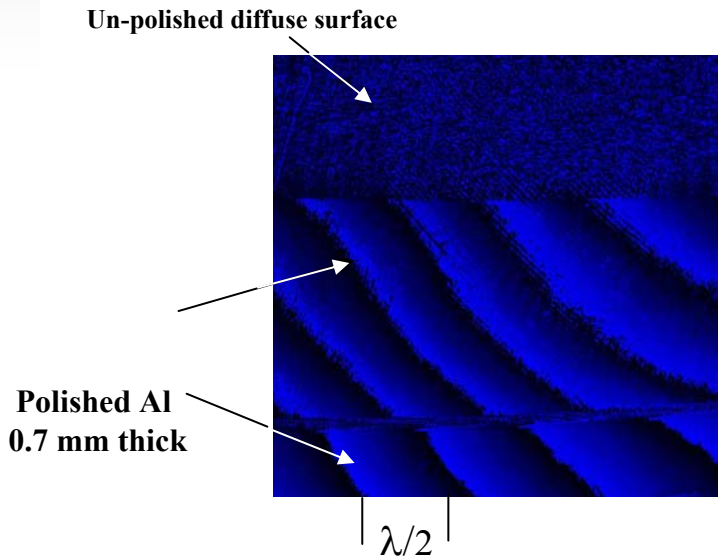
A,B,C,D(t)



A_0,B_0,C_0,D_0

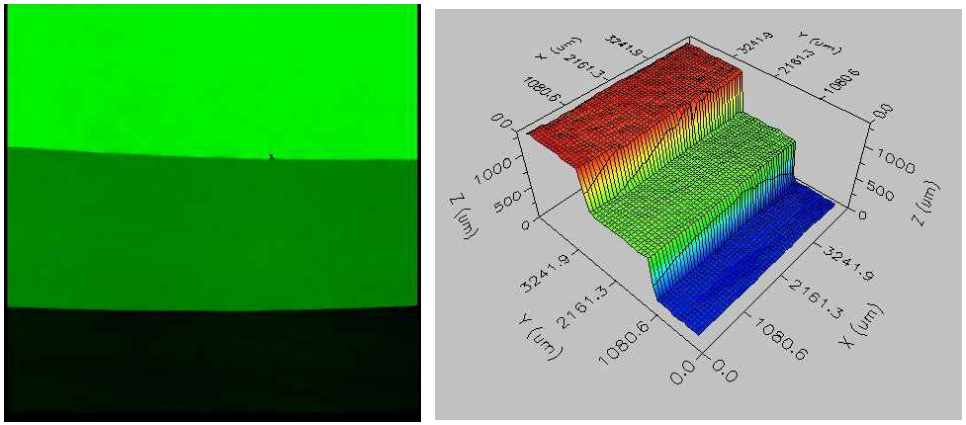
Measurement of polished and unpolished substrates

Single λ phasemap



Discontinuities not resolved
Diffuse surface - random phase
Unwrapping errors

Dual λ phasemap



True 3D measurement

Discontinuity resolved
1 fringe = 3 mm

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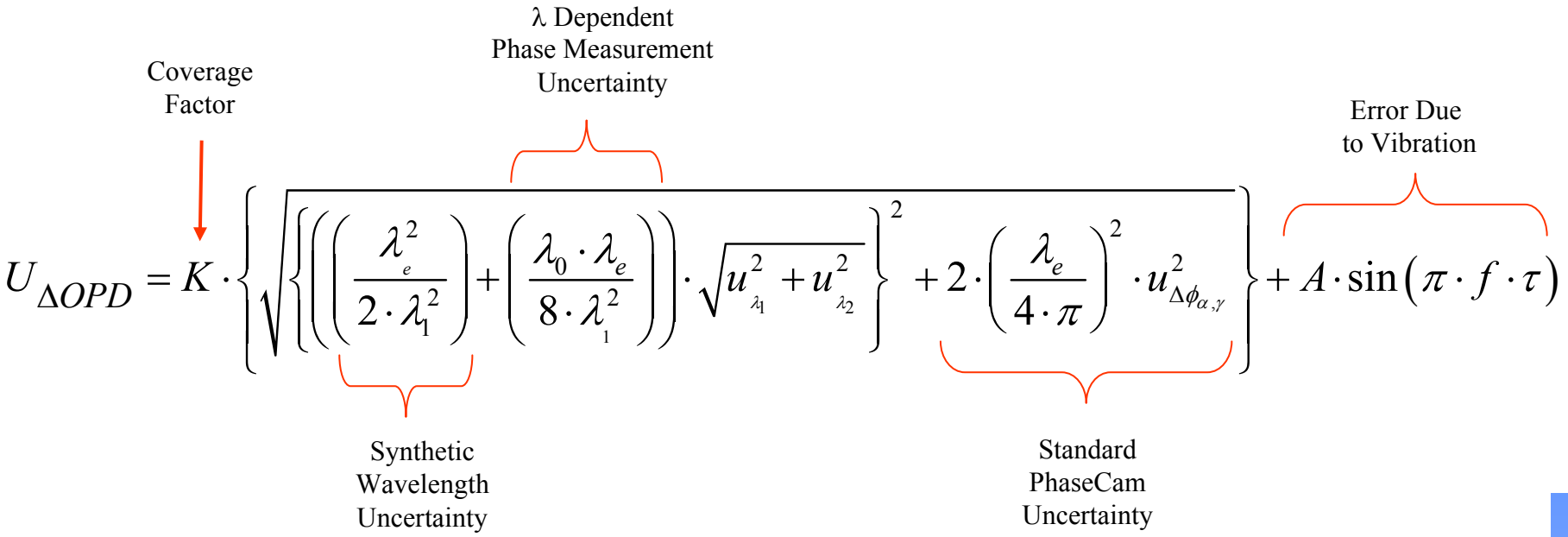
2 Wavelength Measurement Uncertainty



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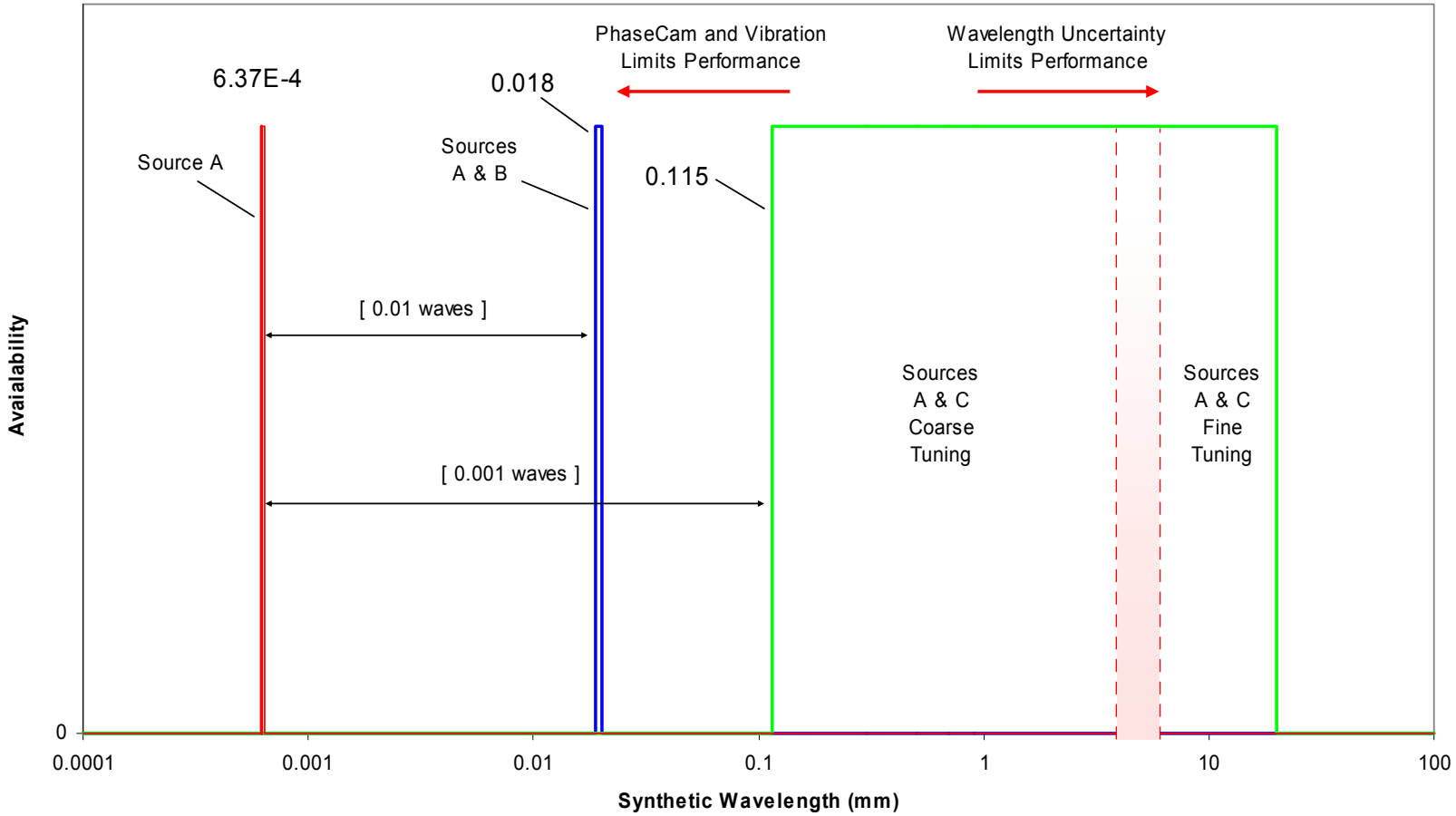
Synthetic Wavelength Coverage



- Uncertainty at 0.115 mm must be less than 0.0014 synthetic waves
- Uncertainty at 0.018 mm must be less than 0.0088 synthetic waves
- Need three sources to cover wavelength range

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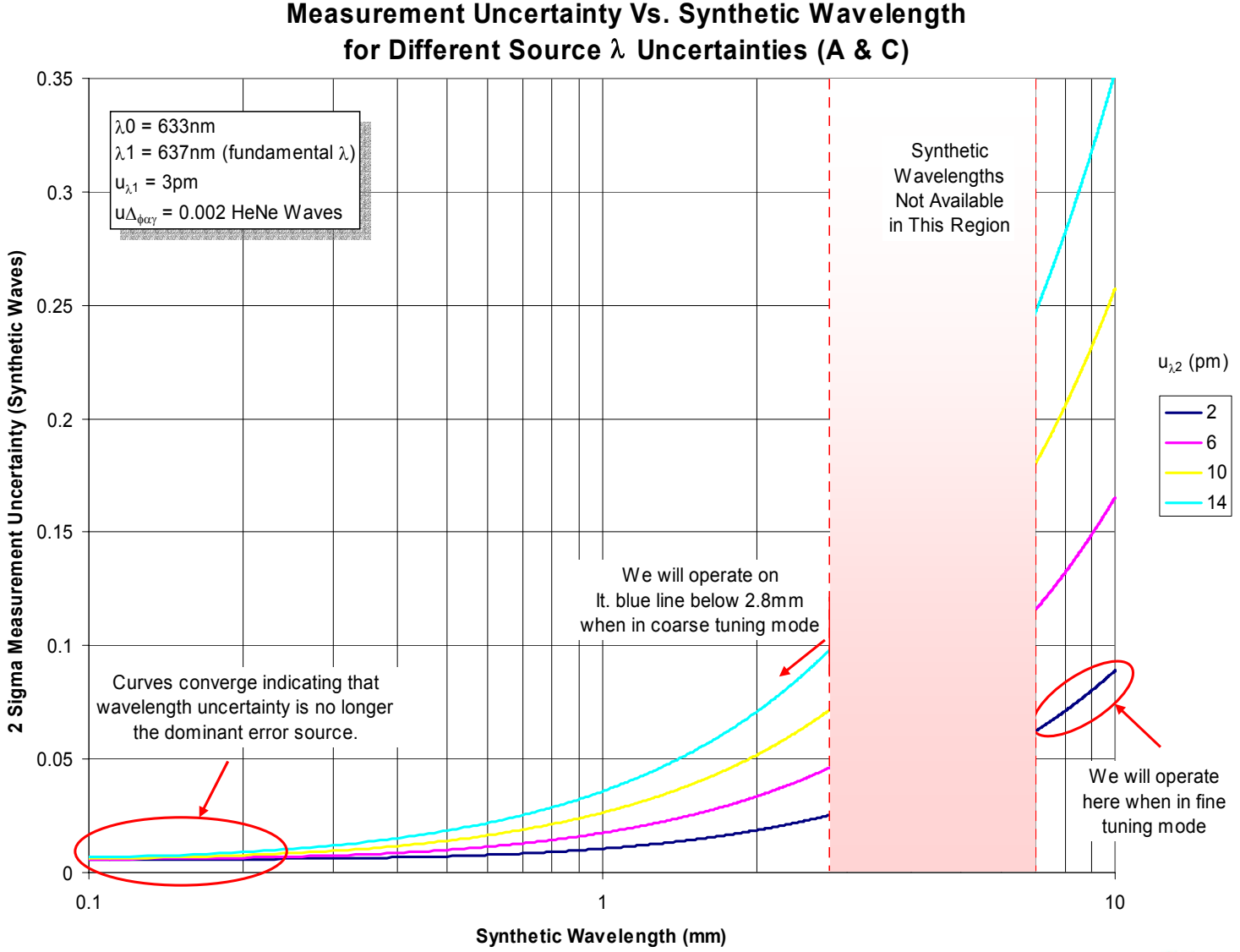

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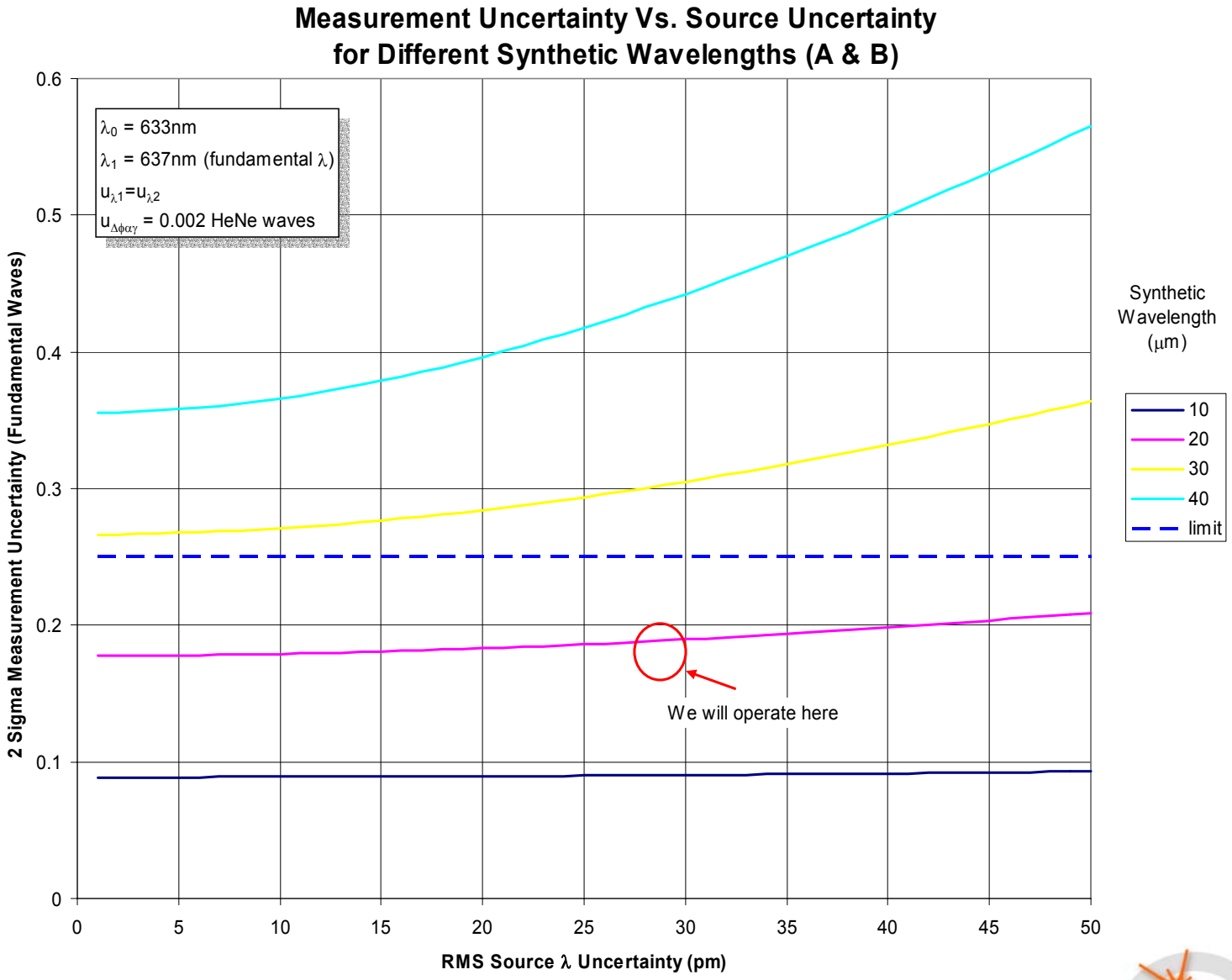

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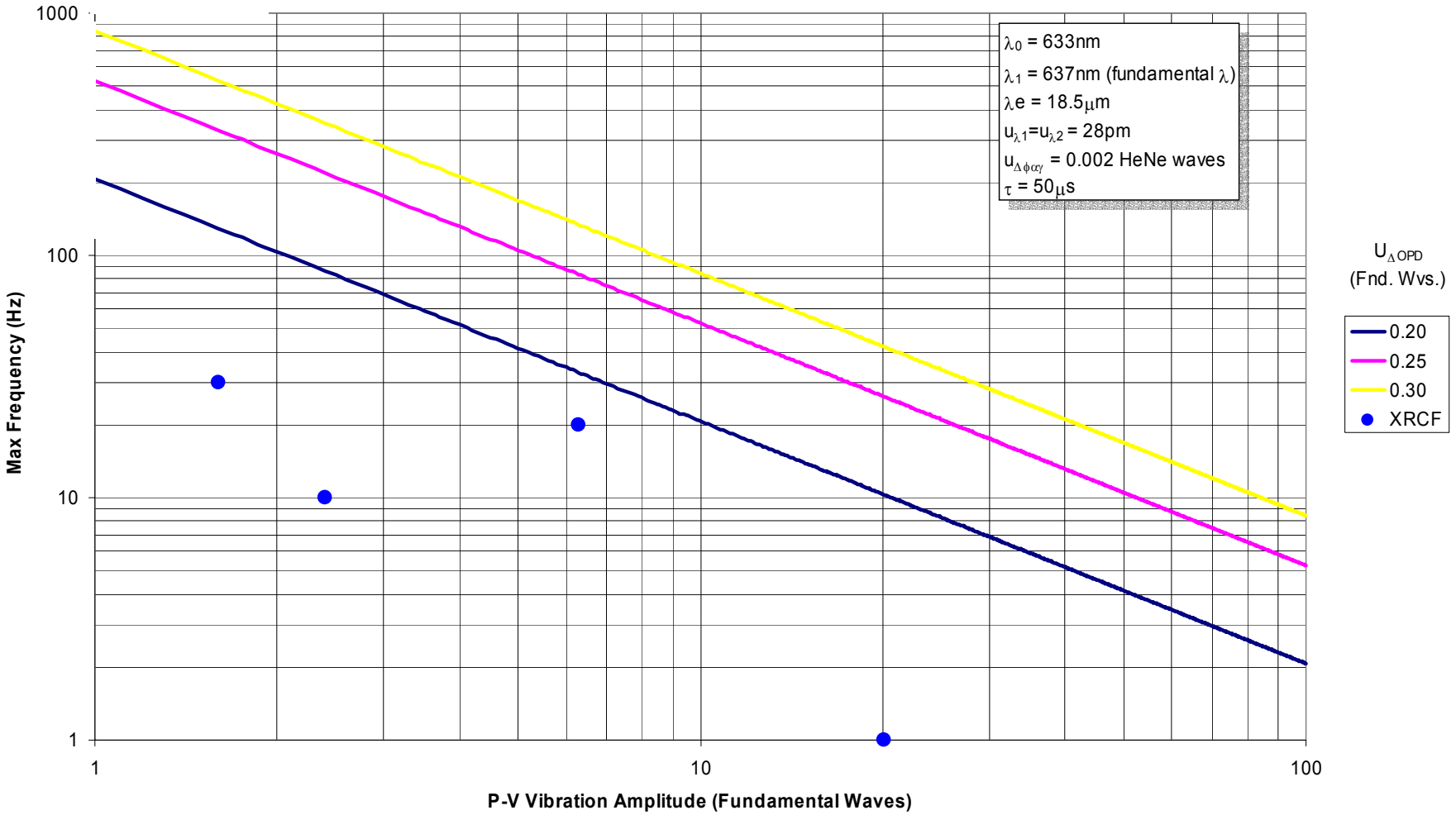
Frequency Response



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Project Status

- Uncertainty Analysis is Complete
- Sources Have Been Selected
- Coupling Configuration Has Been Designed
- Optical Components Have Been Selected
- Source Module Components Are On Order
- Mechanical Design is 80% Complete
- Measurement Process Has Been Outlined
- Software Changes Are in Progress

Project is On Schedule!!

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Modal Analysis

Vibrational measurement of mirrors

- New Generation Mirrors:
  - large mirrors (10's meters)
  - lightweight
  - multi-laminate
- Susceptibility to low freq. resonant modes
  - Performance and integrity issues
  - FEM used in design
  - Actual measurements tell whole story
- Measurement requirements
  - High resolution (sub-wavelength)
  - No mass loading

Interferometry is needed

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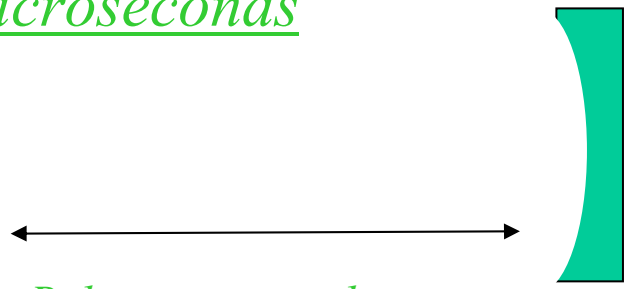
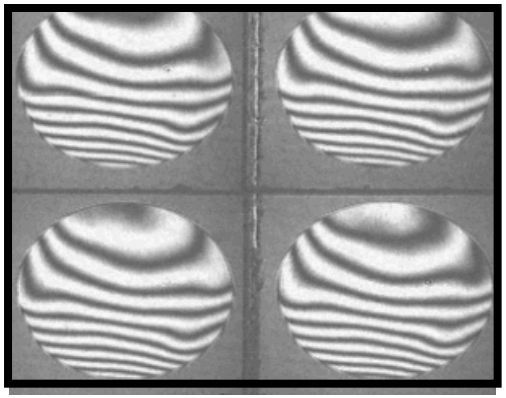
Effects of vibration

Acquisition time ~ 30 microseconds



Relative motion between PhaseCam and test object



Subtract two measurements to find vibration!

Phase relationship is fixed
Measure surface + tilt

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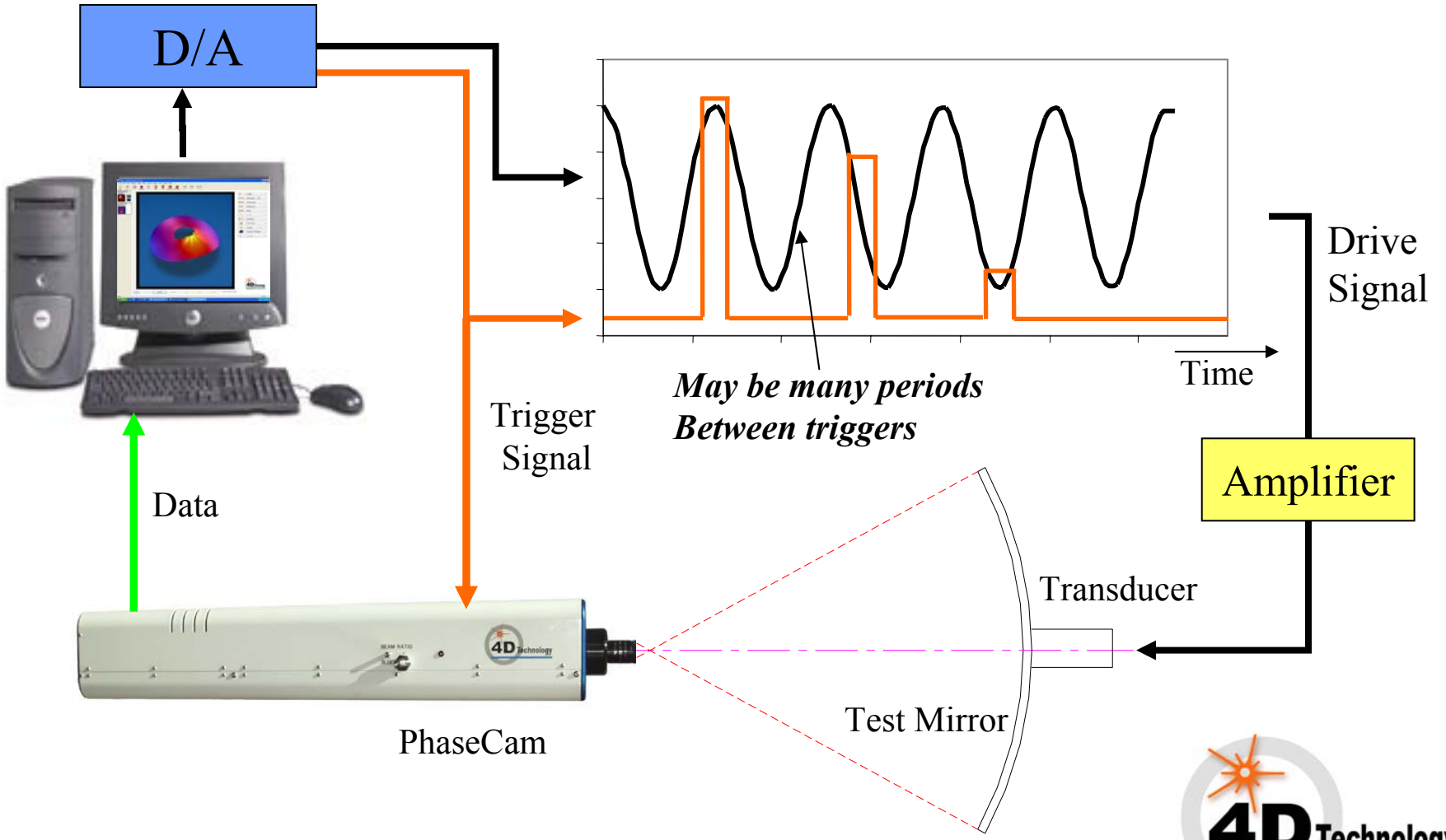
Synchronous Measurement



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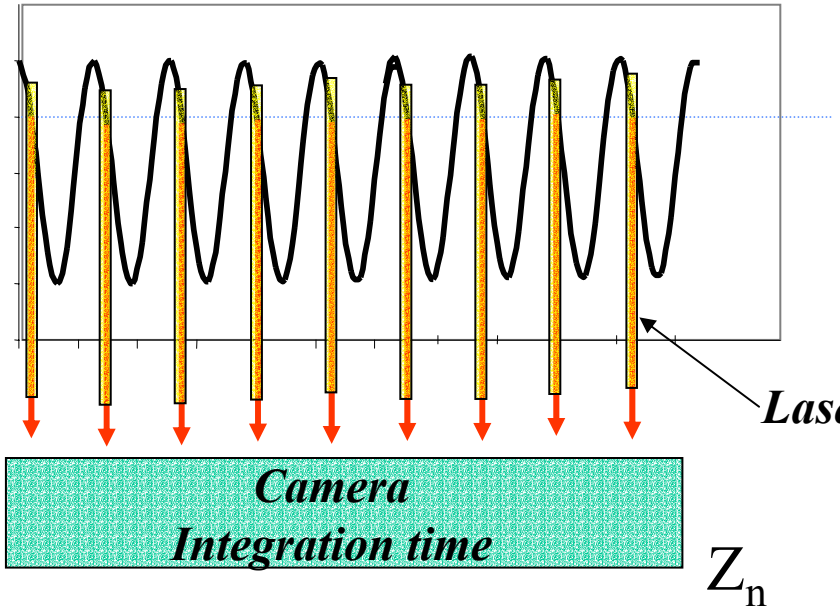
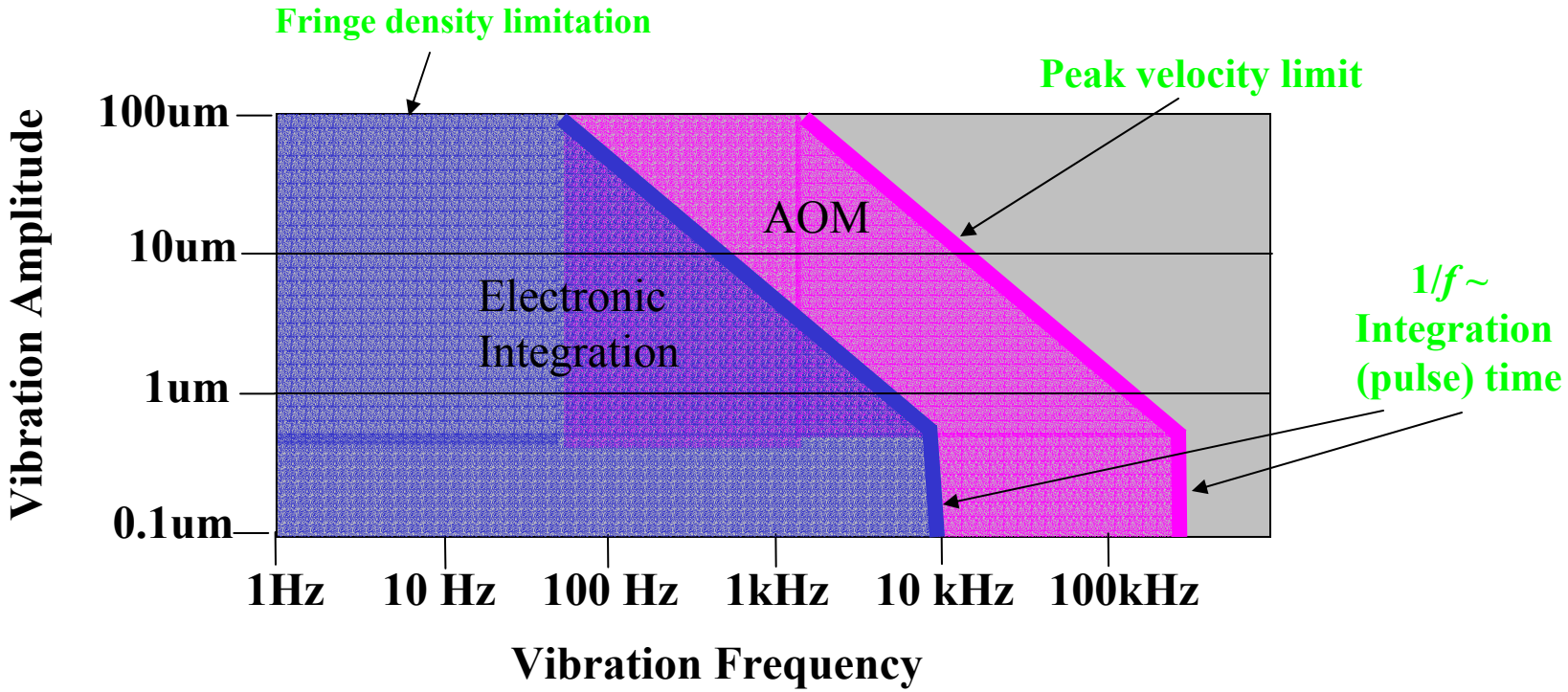
Synchronous – shutter laser

Acousto-optic modulator ~ sub-microsecond



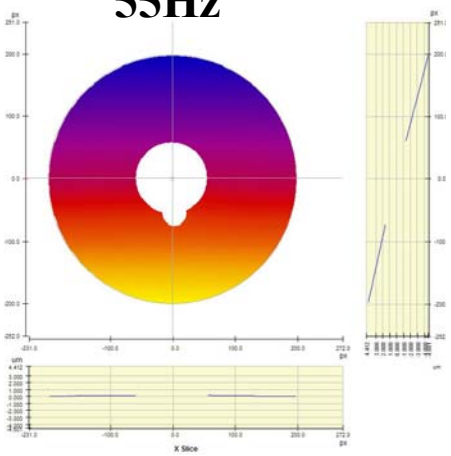
Extends
Frequency Range

Operational Limits

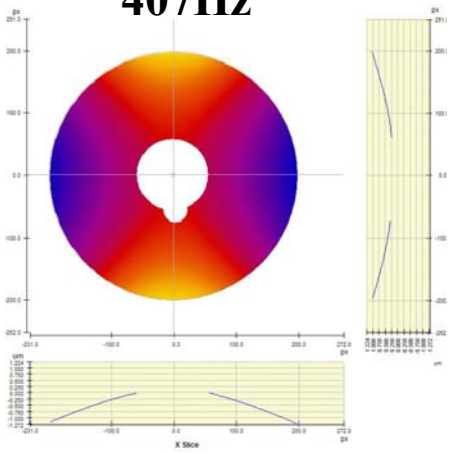


Several Resonant Modes

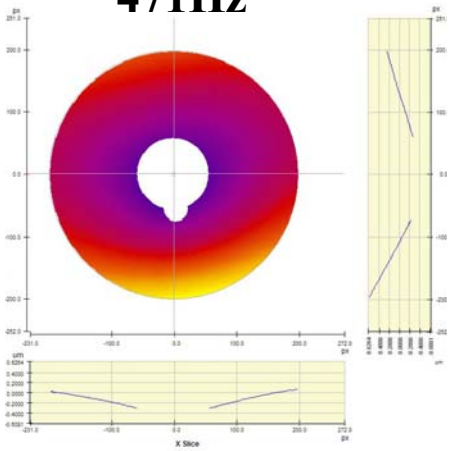
55Hz



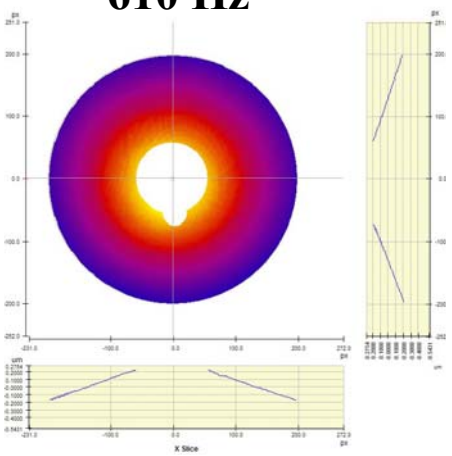
407Hz



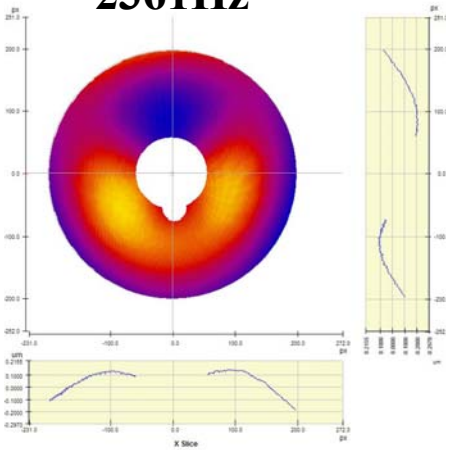
471Hz



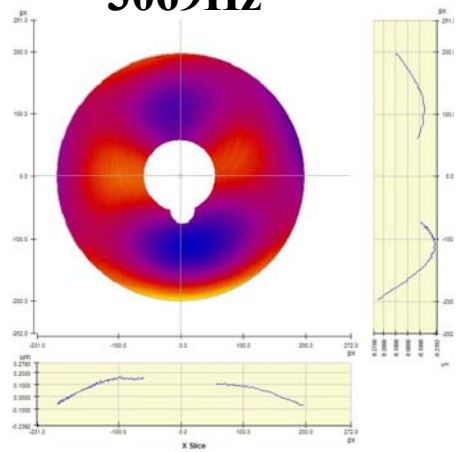
610 Hz



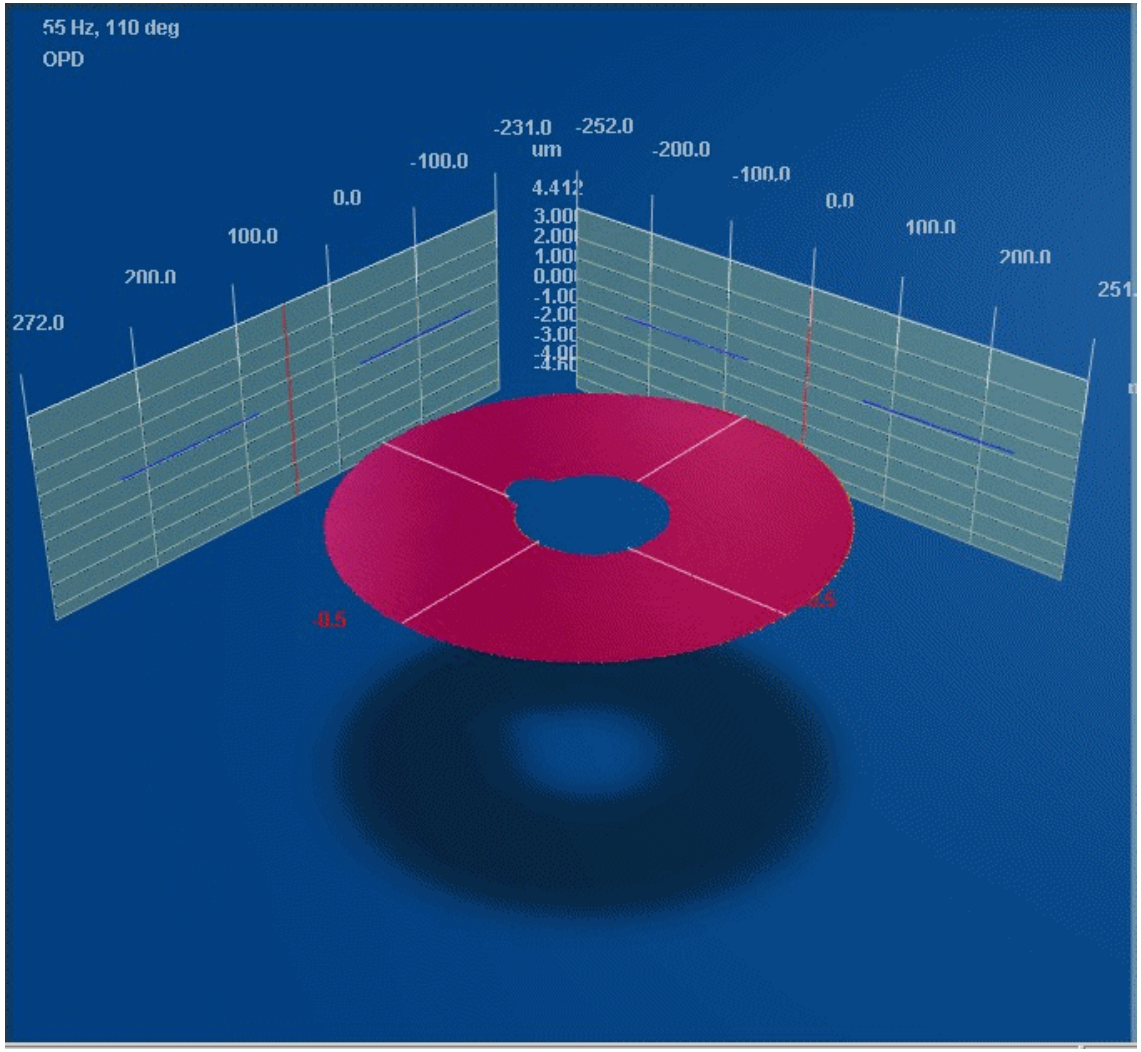
2361Hz



3069Hz



Phase Sweep



Al mirror, 55 Hz, first order mode

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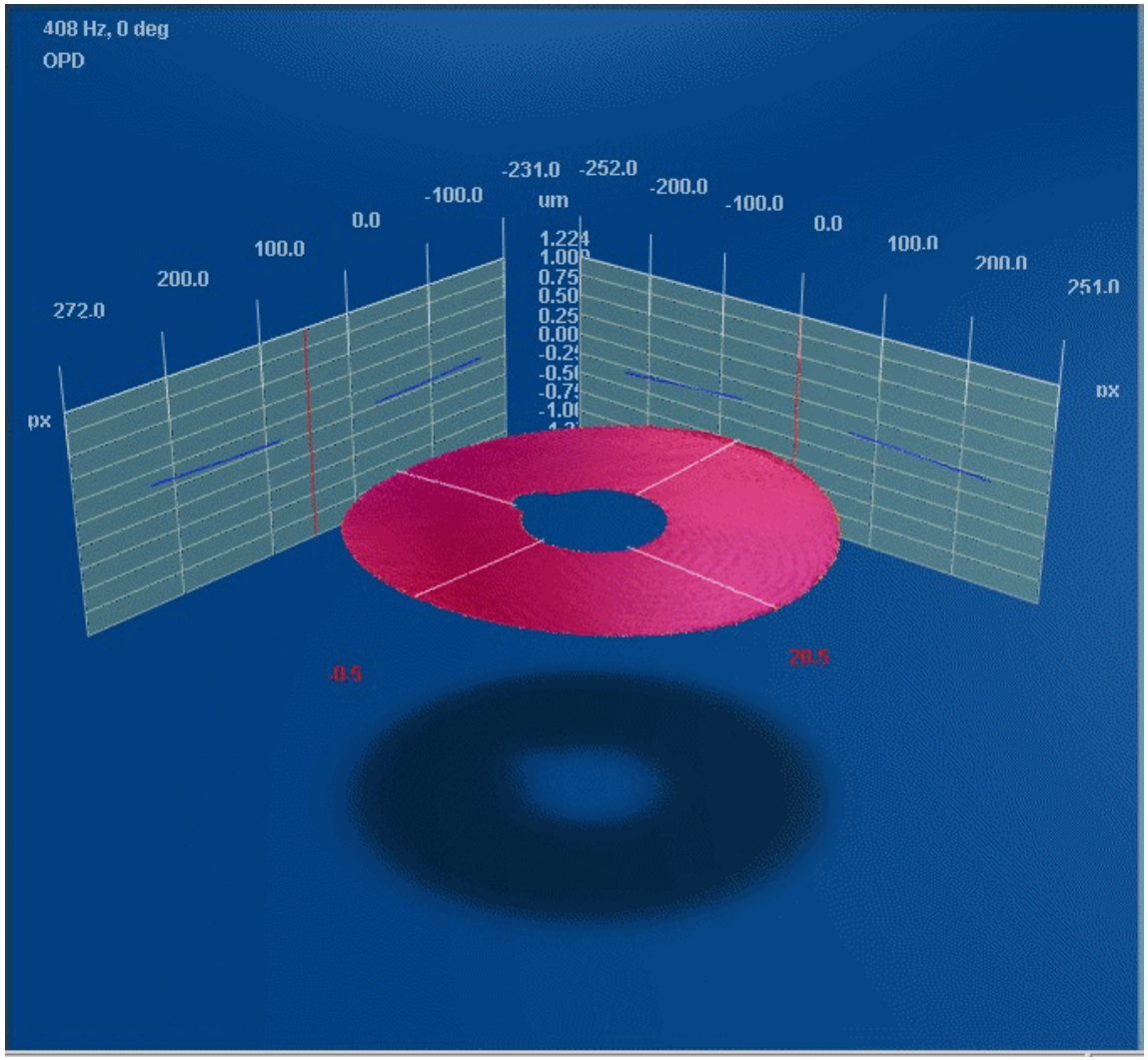
Phase Sweep



Al mirror, 408 Hz

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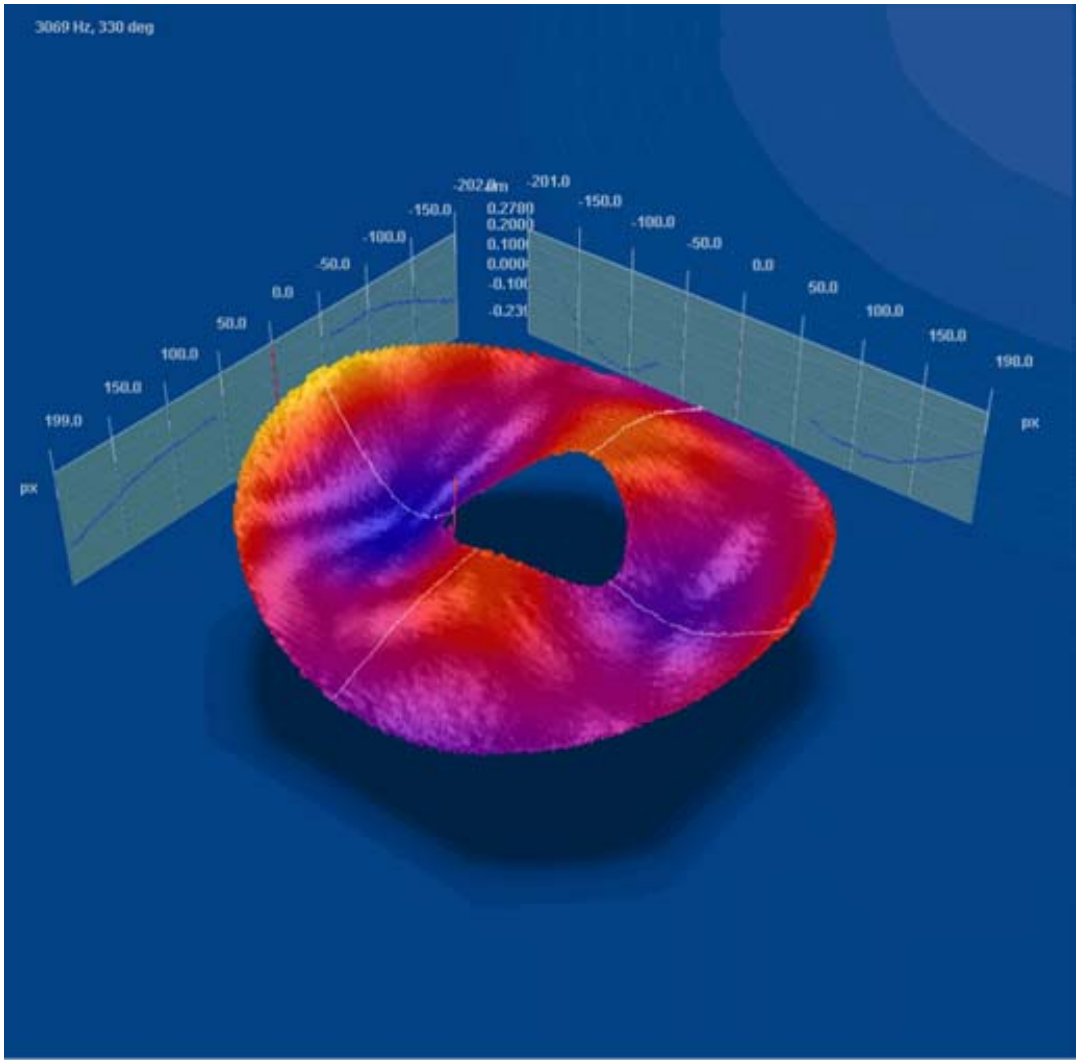
Phase Sweep



Al mirror, 3069 Hz, higher order mode

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Conclusions

- PhaseCam Capabilities
  - High resolution surface figure measurement
  - Two-wavelength measurements
  - Differential surface measurement (specular and diffuse surfaces)
- Multiple Wavelength PhaseCam Development is on Schedule
- Modal Analysis Has Been Implemented
  - Wide frequency response (sub Hz – 100kHz)
  - Accurate determination of modal deflection (<10nm)
  - Sweeping over frequency and/or phase

CONTACT INFORMATION

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